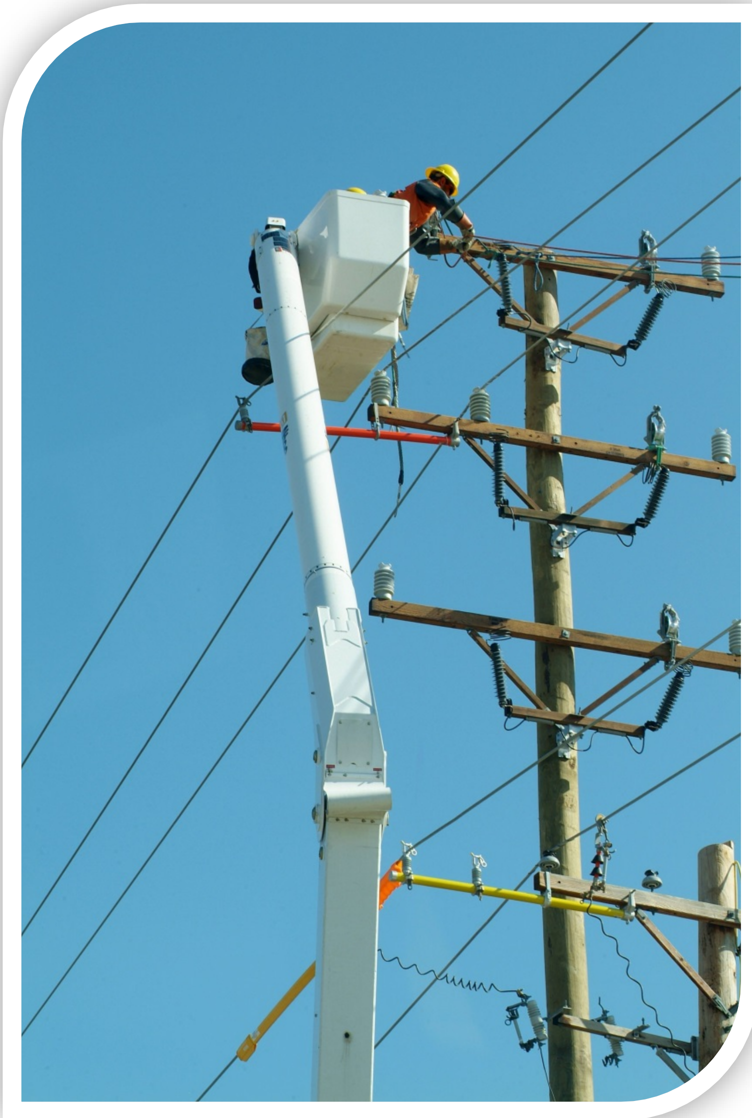
Electrical Safety Basics



OSHAcademy Course 715 Study Guide

Electrical Safety Basics

Contact OSHAcademy to arrange for use as a training document.

This study guide is designed to be reviewed off-line as a tool for preparation to successfully complete OSHAcademy Course 715.

Read each module, answer the quiz questions, and submit the quiz questions online through the course webpage. You can print the post-quiz response screen which will contain the correct answers to the questions.

The final exam will consist of questions developed from the course content and module quizzes.

We hope you enjoy the course and if you have any questions, feel free to email or call:

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Contents

Course Introduction

This course describes the hazards of electrical work and basic approaches to working safely. You will learn skills to help you recognize, evaluate, and control electrical hazards. This information will prepare you for additional safety training such as hands-on exercises and more detailed reviews of regulations for electrical work.

Take a look at the top 10 most cited standards for the FY 2013 (National Safety Council) and you will see that electrical safety is a part of two of the commonly cited violations.

1. Fall protection (1926.451)
2. Hazard Communication (1910.1200)
3. Scaffolding (1926.451)
4. Respiratory protection (1910.134)
5. **Electrical, Wiring (1910.305)**
6. Powered Industrial Trucks (1910.178)
7. Ladders (1926.1053)
8. Lockout/Tagout (1919.147)
9. **Electrical, General 1910.303)**
10. Machine Guarding (1910.212)

Your employer, co-workers, and community will depend on your expertise. Start your career off right by learning safe practices and developing good safety habits. Safety is a very important part of any job. Do it right from the start.

This course will present many topics. There are four main types of electrical injuries: electrocution (death due to electrical shock), electrical shock, burns, and falls. The dangers of electricity, electrical shock, and the resulting injuries will be discussed. The various electrical hazards will be described. You will learn about the 3-STEP Electrical Safety Model, an important tool for recognizing, evaluating, and controlling hazards. Important definitions and notes are shown in the margins. Practices that will help keep you safe and free of injury are emphasized. To give you an idea of the hazards caused by electricity, case studies about real-life deaths will be described.

Module 1: Electricity Is Dangerous

Introduction

Whenever you work with power tools or on electrical circuits, there is a risk of electrical hazards, especially electrical shock. Anyone can be exposed to these hazards at home or at work. Workers are exposed to more hazards because job sites can be cluttered with tools and materials, fast-paced, and open to the weather. Risk is also higher at work because many jobs involve electric power tools.

Electrical workers must pay special attention to electrical hazards because they work on electrical circuits. Coming in contact with an electrical voltage can cause current to flow through the body, resulting in electrical shock and burns. Serious injury or even death may occur.

As a source of energy, electricity is used without much thought about the hazards it can cause. Because electricity is a familiar part of our lives, it often is not treated with enough caution. As a result, an average of one worker is electrocuted on the job every day of every year!

Case Study

A 29-year old male welder was assigned to work on an outdoor concrete platform attached to the main factory building. He wheeled a portable arc welder onto the platform. Since there was not an electrical outlet nearby, he used an extension cord to plug in the welder. The male end of the cord had four prongs and the female end was spring-loaded. The worker plugged the male end of the cord into the outlet. At that instant, the metal case around the power cord plug became energized, electrocuting the worker.

An investigation showed that the female end of the extension cord was broken. The spring, cover plate, and part of the casing were missing from the face of the female connector. Also, the grounding prong on the welder power cord plug was so severely bent that it slipped outside the connection. Therefore, the arc welder was not grounded. Normally, it would have been impossible to insert the plug incorrectly.

Do not let this happen to you. Use these safe practices:

- Thoroughly inspect all electrical equipment before beginning to work

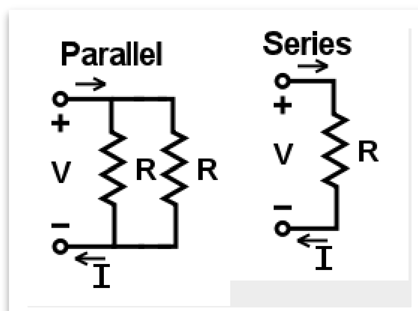
- Do not use extension cords as a substitute for fixed wiring. In this case, a weatherproof receptacle should have been installed on the platform.
- Use connectors that are designed to stand up to the abuse of the job. Connectors designed for light-duty should not be used in an industrial environment.

Terms you need to know

What is "voltage"? Voltage is a measure of the electrical force that seems to push the current along. Think of voltage as a lot of water stored in a high water tank. Because the water tank is high, the water will have more force behind it as it flows down the water pipe to your home. This is why they put water tanks up high! :-) If the same tank was placed at ground level, your water pressure would not be as great. By the way, the symbol for voltage is "V".

What is "amperage"? Amperage is the unit used to measure the amount of electrical current. Amperage is often referred to as "current" by electrical workers and engineers. Let's go back to our water tank. If diameter of your pipe coming from the water tank is large, a lot of water (amperage) will flow through the pipe. If the pipe's diameter is small, a smaller amount of water will flow through the pipe. If you need a lot of current (many amps) to operate your equipment, you'll need large wires to run the current or they'll burn up! The symbol for amperage is "I".

What is "resistance"? Resistance is the unit (ohms) used to measure the opposition to the flow of electrical current. This is pretty easy to understand. A small water pipe is going to oppose a lot of water from flowing. Relatively little water will be able to flow through the pipe. So, the pipe offers a high resistance to the flow of water. You can see that a large pipe would offer little resistance to the flow of water. Big pipe: a lot of water! It's that simple. In an electrical circuit, components are usually sources of resistance. Any component that heats up due to electrical current is a source of resistance. The symbol for resistance is "R".



What is a "circuit"? A circuit is the complete path for the flow of current. Electrical current may flow through a circuit through a series or through a parallel path.

- What's a "series" circuit? The current in a series circuit takes only one path. For example, water from high in the mountains may flow down one stream (series) into a river that flows to the ocean.

- What's a "parallel" circuit? The current in a parallel circuit takes many paths. For example, the water flowing from a water tank up on a hill will flow through many different water pipes (parallel) before it reaches the ocean.

Case Study

A female assistant manager of a swim club was instructed to add a certain chemical to the pool. She went down into the pump room, barefoot. The room was below ground level and the floor was covered with water. She filled a plastic drum with 35-40 gallons of water, then plugged a mixing motor into a 120-volt wall outlet and turned on the motor. The motor would be used to mix the water and the chemical. Then the solution would be added to the pool. While adding the chemical to the water in the drum, she contacted the mixing motor with her left hand. Apparently, the motor had developed a ground fault. Because of the ground fault, the motor was energized and she was electrocuted. A co-worker found the victim slumped over the drum with her face submerged in water. The co-worker tried to move the victim, but was shocked. The assistant manager was dead on arrival at a local hospital.

An investigation showed that the mixing motor was in poor condition. The grounding pin had been removed from the male end of the power cord, resulting in a faulty ground. The circuit was equipped with a GFCI, but it was not installed properly. A properly wired and functioning GFCI could have sensed the ground fault in the motor and de-energized the circuit.

Take a look at what could have been done to prevent this death:

- The employer should have kept the motor in better condition. Power cords should be inspected regularly, and any missing ground prongs should be replaced.
- All pool-area electrical circuits should be installed by qualified electricians.
- The victim should have worn insulating boots or shoes since she was handling electrical equipment.
- The employer should have followed the law. The NEC requires that all pool-associated motors have a permanent grounding system. In this case, this regulation was not followed. Also, electrical equipment is not permitted in areas without proper drainage.

- OSHA requires employers to provide a work environment free of safety and health hazards.

How do you receive an electrical shock?

Always test a circuit to make sure it is de-energized before working on it.

An electrical shock is received when electrical current passes through the body. Current will pass through the body in a variety of situations. Whenever two wires are at different voltages, current will pass between them if they are connected. Your body can connect the wires, or what electrical workers call "complete the circuit". If you touch both of them at the same time, current will pass through your body.

In most household wiring in the U.S., the black wires and the red wires are at 120 volts. The white wires are at 0 volts because they are connected to ground. The connection to ground is often through a conducting ground rod driven into the earth.

If you come in contact with an energized black wire- and you are also in contact with the neutral white wire- current will pass through your body. You will receive an electrical shock.

Metal electrical boxes should be grounded to prevent shocks.

You can even receive a shock when you are not in contact with an electrical ground. Contact with both live wires of a 240-volt cable will deliver a shock. (This type of shock can occur because one live wire may be at +120 volts while the other is at -120 volts during an alternating current cycle-a difference of 240 volts.). You can also receive a shock from electrical components that are not grounded properly. Even contact with another person who is receiving an electrical shock may cause you to be shocked.

Case Study

A 30- year-old male electrical technician was helping a company service representative test the voltage-regulating unit on a new rolling mill. While the electrical technician went to get the equipment service manual, the service representative opened the panel cover of the voltage regulators control cabinet in preparation to trace the low-voltage wiring in question. (the wiring was not color-coded) The service representative climbed onto a nearby cabinet in order to view the wires. The technician returned and began working inside the control cabinet, near exposed and energized electrical conductors. The technician tugged at the low-voltage wires while the service representative tried to identify them from above. Suddenly, the representative heard the victim making a gurgling sound and looked down to see the victim shaking as though he were being shocked. Cardiopulmonary resuscitation (CPR) was administrated to the victim about 10 minutes later. He was pronounced dead almost two hours later as a result of his contact with an energized electrical conductor.

To prevent an incident like this, employers should take the following steps:

- Establish proper rules and procedures on how to access electrical control cabinets without getting hurt.
- Make sure all employees know the importance of de-energizing (shutting off) electrical systems before preforming repairs.
- Equip voltage-regulating equipment with color-coded wiring.
- Train workers in CPR.

Module 1 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. ___________ is a measure of the electrical force that seems to push the current along.

a. amperage
b. resistance
c. voltage
d. reluctance

2. _______ is the unit used to measure the amount of electrical current.

a. amperage
b. resistance
c. voltage
d. reluctance

3. _______ is the unit (ohms) used to measure the opposition to the flow of electrical current.

a. amperage
b. resistance
c. voltage
d. reluctance

4. Whenever two wires are at different _________, current will pass between them if they are connected.

a. lengths
b. voltages
c. resistance
d. heights

5. You can receive an electrical shock when you are not in contact with an electrical ground.

a. True
b. False

Module 2: The Dangers of Electrical Shock

Severity of electrical shock

The severity of injury from electrical shock depends on the amount of electrical amperage (current) and the length of time the current passes through the body. For example, 1/10 of an ampere (amp) of electricity going through the body for just 2 seconds is enough to cause death.

The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand can be less than 10 milliamperes (milliamps or mA).

Currents above 10 mA can paralyze or "freeze" muscles. When this "freezing" happens, a person is no longer able to release a tool, wire, or other object. In fact, the electrified object may be held even more tightly, resulting in longer exposure to the shocking current. For this reason, hand-held tools that give a shock can be very dangerous.

If you can't let go of the tool, current continues through your body for a longer time, which can lead to respiratory paralysis (the muscles that control breathing cannot move). You stop breathing for a period of time.

People have stopped breathing when shocked with currents from voltages as low as 49 volts. Usually, it takes about 30 mA of current to cause respiratory paralysis.

Currents greater than 75 mA may cause ventricular fibrillation (very rapid, ineffective heartbeat). This condition will cause death within a few minutes unless a special device called a defibrillator is used to save the victim. Heart paralysis occurs at 4 amps, which means the heart does not pump at all.

Tissue is burned with currents greater than 5 amps.

The table below shows what usually happens for a range of currents (lasting one second) at typical household voltages. Longer exposure times increase the danger to the shock victim. For example, a current of 100 mA applied for 3 seconds is as dangerous as a current of 900 mA applied for a fraction of a second (0.03 seconds).

The muscle structure of the person also makes a difference. People with less muscle tissue are typically affected at lower current levels. Even low voltages can be extremely dangerous because the degree of injury depends not only on the amount of current but also on the length of time the body is in contact with the circuit.

Low Voltage Does Not Mean Low Hazard!

Effects of Electrical Current* on the Body	
Current	Reaction
1 milliamp	Just a faint tingle.
5 milliamps	Slight shock felt. Disturbing, but not painful. Most people can "let go." However, strong involuntary movements can cause injuries.
6-25 milliamps (women)† 9-30 milliamps (men)	Painful shock. Muscular control is lost. This is the range where "freezing currents" start. It may not be possible to "let go."
50-150 milliamps	Extremely painful shock, respiratory arrest (breathing stops), severe muscle contractions. Flexor muscles may cause holding on; extensor muscles may cause intense pushing away. Death is possible.
1,000-4,300 milliamps (1-4.3 amps)	Ventricular fibrillation (heart pumping action not rhythmic) occurs. Muscles contract; nerve damage occurs. Death is likely.
10,000 milliamps (10 amps)	Cardiac arrest and severe burns occur. Death is probable.

15,000 milliamps (15 amps)	Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!
*Effects are for voltages less than about 600 volts. Higher voltages also cause severe burns. †Differences in muscle and fat content affect the severity of shock.	

High Voltage

Sometimes high voltages lead to additional injuries. High voltages can cause violent muscular contractions. You may lose your balance and fall, which can cause injury or even death if you fall into machinery that can crush you. High voltages can also cause severe burns.

At 600 volts, the current through the body may be as great as 4 amps, causing damage to internal organs such as the heart. High voltages also produce burns. In addition, internal blood vessels may clot. Nerves in the area of the contact point may be damaged. Muscle contractions may cause bone fractures from either the contractions themselves or from falls.

Third degree burn from a high-voltage line.

There have been cases where an arm or leg is severely burned by high-voltage electrical current to the point of coming off, and the victim is not electrocuted. In these cases, the current passes through only a part of the limb before it goes out of the body and into another conductor. Therefore, the current does not go through the chest area and may not cause death, even though the victim is severely disfigured. If the current does go through the chest, the person will almost surely be electrocuted. A large number of serious electrical injuries involve current passing from the hands to the feet. Such a path involves both the heart and lungs. This type of shock is often fatal.

Electrical burn on hand and arm.

A severe shock can cause much more damage to the body than is visible. A person may suffer internal bleeding and destruction of tissues, nerves, and muscles. Sometimes the hidden injuries caused by electrical shock result in a delayed death. Shock is

often only the beginning of a chain of events. Even if the electrical current is too small to cause injury, your reaction to the shock may cause you to fall, resulting in bruises, broken bones, or even death.

The length of time of the shock greatly affects the amount of injury. If the shock is short in duration, it may only be painful. A longer shock (lasting a few seconds) could be fatal if the level of current is high enough to cause the heart to go into ventricular fibrillation. This is not much current when you realize that a small power drill uses 30 times as much current as what will kill. At relatively high currents, death is certain if the shock is long enough. However, if the shock is short and the heart has not been damaged, a normal heartbeat may resume if contact with the electrical is eliminated. (This type of recovery is rare.)

The amount of current passing through the body also affects the severity of an electrical shock. Greater voltages produce greater currents. So, there is greater danger from higher voltages. Resistance hinders current. The lower the resistance (or impedance in AC circuits), the greater the current will be.

Dry skin may have a resistance of 100,000 ohms or more. Wet skin may have a resistance of only 1,000 ohms. Wet working conditions or broken skin will drastically reduce resistance. The low resistance of wet skin allows current to pass into the body more easily and give a greater shock. When more force is applied to the contact point or when the contact area is larger, the resistance is lower, causing stronger shocks.

The path of the electrical current through the body affects the severity of the shock. Currents through the heart or nervous system are most dangerous. If you contact a live wire with your head, your nervous system will be damaged. Contacting a live electrical part with one hand-while you are grounded at the other side of your body-will cause electrical current to pass across your chest, possibly injuring your heart and lungs.

Case Study

A male technician arrived at a customer's house to perform pre-winter maintenance on an oil furnace. The customer then left the house and returned 90 minutes later. She noticed the service truck was still in the driveway. After 2 more hours, the customer entered the crawl space with a flashlight to look for the technician, but couldn't see him. She then called the owner of the company, who came to the house. He searched the crawl space and found the technician on his stomach, leaning on his elbows in front of the furnace. The assistant county coroner was called and pronounced the technician dead at the scene. The victim had electrical

burns on his scalp and right elbow.

After the incident, an electrician inspected the site. A toggle switch that supposedly controlled electrical power to the furnace was in the "off" position. The electrician described the wiring as "haphazard and confusing."

Two weeks later, the county electrical inspector performed another inspection. He discovered that incorrect wiring of the toggle switch allowed power to flow to the furnace even when the switch was in the off position. The owner of the company stated that the victim was a very thorough worker. Perhaps the victim performed more maintenance on the furnace than previous technicians, exposing him to the electrical hazard.

This death could have been prevented!

- The victim should have tested the circuit to make sure it was de-energized.
- Employers should provide workers with appropriate equipment and training. Using safety equipment should be a requirement of the job. In this case, a simple circuit tester may have saved the victim's life.
- Residential wiring should satisfy the National Electrical Code (NEC). Although the NEC is not retroactive, all homeowners should make sure their systems are safe.

Module 2 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. According to the text, the severity of injury from electrical shock depends on which two factors below?

a. resistance, voltage
b. amperage, length of time
c. length of time, voltage
d. resistance, length of time

2. People have stopped breathing when shocked with currents from voltages as low as ______ volts.

a. 600
b. 125
c. 49
d. 6

3. An electrical current of _________ can cause extremely painful shock, respiratory arrest, (breathing stops) and severe muscle contractions.

a. 1-10 milliamps
b. 6-25 milliamps
c. 10-40 milliamps
d. 50-150 milliamps

4. At ____ volts, the current through the body may be as great as 4 amps, causing damage to internal organs such as the heart.

a. 600
b. 480
c. 120
d. 50

5. Which of the following will result in the lowest resistance and greater risk of injury when shocked?

a. dirty skin
b. dry skin
c. wet skin
d. thin skin

Module 3: Electrical Burns

What is the most common injury?

The most common shock-related, nonfatal injury is a burn. Burns caused by electricity may be of three types: electrical burns, arc burns, and thermal contact burns. Electrical burns can result when a person touches electrical wiring or equipment that is used or maintained improperly. Typically, such burns occur on the hands. Electrical burns are one of the most serious injuries you can receive. They need to be given immediate attention. Additionally, clothing may catch fire and a thermal burn may result from the heat of the fire.

Arc-blasts occur when powerful, high-amperage currents arc through the air. Arcing is the luminous electrical discharge that occurs when high voltages exist across a gap between conductors and current travels through the air. This situation is often caused by equipment failure due to abuse or fatigue. Temperatures as high as 35,000°F have been reached in arc-blasts.

Definitions of terms:

- *arc-blast-explosive:* release of molten material from equipment caused by high-amperage arcs
- *arcing:* the luminous electrical discharge (bright, electrical sparking) through the air that occurs when high voltages exist across a gap between conductors

Arc Blast Hazards

Contact electrical burns. The knee on the left was energized, and the knee on the right was grounded.

There are three primary hazards associated with an arc-blast.

1. Arcing during an arc blast gives off thermal radiation (heat) and intense light, which can cause burns. Several factors affect the degree of injury, including skin color, area of skin exposed, and type of clothing worn. Proper clothing, work distances, and overcurrent protection can reduce the risk of such a burn.

2. A high-voltage arc can produce a considerable pressure wave blast. A person 2 feet away from a 25,000-amp arc feels a force of about 480 pounds on the front of the body. In addition, such an explosion can cause serious ear damage and memory loss due to concussion. Sometimes the pressure wave throws the victim away from the arc-blast. While this may reduce further exposure to the thermal energy, serious physical injury may result. The pressure wave can propel large objects over great distances. In some cases, the pressure wave has enough force to snap off the heads of steel bolts and knock over walls.
3. A high-voltage arc can also cause many of the copper and aluminum components in electrical equipment to melt. These droplets of molten metal can be blasted great distances by the pressure wave. Although these droplets harden rapidly, they can still be hot enough to cause serious burns or cause ordinary clothing to catch fire, even if you are 10 feet or more away.

Case Study

Five technicians were performing preventive maintenance on the electrical system of a railroad maintenance facility. One of the technicians was assigned to clean the lower compartment of an electrical cabinet using cleaning fluid in an aerosol can. But, he began to clean the upper compartment as well. The upper compartment was filled with live circuitry. When the cleaning spray contacted the live circuitry, a conductive path for the current was created. The current passed through the stream of fluid, into the technician's arm, and across his chest. The current caused a loud explosion. Co-workers found the victim with his clothes on fire. One worker put out the fire with an extinguisher and another pulled the victim away from the compartment with a plastic vacuum cleaner hose. The paramedics responded in five minutes. Although the victim survived the shock, he died 24 hours later because of the burns.

This death could have been prevented if the following precautions had been taken:

- Before doing any electrical work, de-energize all circuits and equipment. Perform lockout/tagout, and test circuits and equipment to make sure they are de-energized.
- The company should have trained the workers to perform their jobs safely.
- Proper personal protective equipment (PPE) should always be used.
- Never use aerosol spray cans around high-voltage equipment.

Extinguishing the fire

Electricity is one of the most common causes of fires and thermal burns in homes and workplaces. Defective or misused electrical equipment is a major cause of electrical fires. If there is a small electrical fire, be sure to use only a Class C or multipurpose (ABC) fire extinguisher, or you might make the problem worse. All fire extinguishers are marked with letter(s) that tell you the kinds of fires they can put out. Some extinguishers contain symbols, too.

The letters and symbols are explained below (including suggestions on how to remember them):

A  A (think: Ashes) = paper, wood, etc.

B  B (think: Barrel) = flammable liquids

C  C (think: Circuits) = electrical fires

Thermal burns may result if an explosion occurs when electricity ignites an explosive However, do not try to put out fires unless you have received proper training. If you are not trained, the best thing you can do is evacuate the area. This ignition can result from the buildup of combustible vapors, gasses, or dusts. Occupational Safety and Health Administration (OSHA) standards, the NEC, and other safety standards give precise safety requirements for the operation of electrical systems and equipment in such dangerous areas. Ignition can also be caused by overheated conductors or equipment, or by normal arcing at switch contacts or in circuit breakers.

Training on fire extinguisher use should include hands-on use of a fire extinguisher.

This extinguisher can only be used on Class B and Class C fires.

This extinguisher can only be used on Class A and Class C fires.

Here are a couple of fire extinguishers popular at a worksite. Can you tell what types of fires they will put out?

Case Study

A 29-year-old male maintenance worker was found at 3:45 am lying on his back and convulsing. An overturned cart and an electric welding machine were next to him and lying in a pool of water on the concrete floor. Arcing was visible between the welding machine and the floor. The worker was transported to the closest hospital, where he was pronounced dead.

An examination of the welding machine showed there were exposed conductors in the machine's cables. There were numerous cuts and scrapes in the cables' insulation. On other parts of the machine, insulation was damaged or missing. Also, the machine didn't have a ground connection.

Investigators concluded the maintenance worker was electrocuted when he tried to turn off the welding machine, which was sitting on the cart. The metal frame of the machine had become energized due to the damaged insulation. When he touched the energized frame, he completed the conducting path to ground. The current travelled through his body to ground. Since he was probably standing in water, the risk of a ground fault was even greater.

You must take steps to decrease such hazards in your workplace:

- Ground circuits and equipment.
- Keep all equipment in good operating condition with a preventive maintenance program.
- Never use electrical equipment or work on circuits in wet areas. If you find water or dampness, notify your supervisor immediately.

Module 3 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. Which of the following is not one of the most common shock-related, nonfatal injury?

a. electrical burn
b. chemical burn
c. arc flash burn
d. thermal contact burn

2. This explosive event gives off thermal radiation (heat) and intense light, which can cause burns:

a. arc blast
b. microwave burst
c. voltage wave
d. resistance failure

3. If there is a small electrical fire, be sure to use only a class __________ fire extinguisher, or you might make the problem worse.

a. A or K
b. B or DE
c. C or ABC
d. any of the above

4. If a shock victim is still in contact with an energized circuit and you cannot shut off electrical current quickly, what should you do?

a. grab the victim with one hand only and pull
b. pry the victim loose using a dry wood pole
c. throw a rope around the victim's neck and pull
d. pry the victim loose with a metal pole

5. Which of the following should you know in case there is an electrical-related injury?

a. location of electricity shut-offs "kill switches"
b. where first-aid supplies are located
c. location of a telephone
d. all of the above

Module 4: The Electrical Safety Model

What Must Be Done to Be Safe?

Report hazards to your supervisor or instructor.

To make sure all employees are safe before, during and after electrical work is performed, electrical workers should follow the three-step process of the *Electrical Safety Model:*

1. recognize hazards
2. evaluate risk
3. control hazards

To be safe, you must think about your job and plan for hazards. To avoid injury or death, you must understand and recognize hazards. You need to evaluate the situation you are in and assess your risks. You need to control hazards by creating a safe work environment, by using safe work practices, and by reporting hazards to a supervisor or teacher.

If you do not recognize, evaluate, and control hazards, you may be injured or killed by the electricity itself, electrical fires, or falls. If you use the safety model to recognize, evaluate, and control hazards, you will be much safer at work.

Use the safety model to:

- Recognize, evaluate, and control hazards.
- Identify electrical hazards.
- Don't listen to reckless, dangerous people.
- Evaluate your risk.
- Take steps to control hazards

Recognize hazards

The first step of the safety model is recognizing the electrical hazards around you. Only then can you avoid or control the hazards. It is best to discuss and plan hazard recognition tasks with your co-workers. Sometimes we take risks ourselves, but when we are responsible for others, we are more careful. Sometimes others see hazards that we overlook. Of course, it is possible to be talked out of our concerns by someone who is reckless or dangerous. Don't take a chance. Careful planning of safety

procedures reduces the risk of injury. Decisions to lock out and tag out circuits and equipment need to be made during this part of the safety model. Plans for action must be made now.

Evaluate hazards

When evaluating hazards, it is best to identify all possible hazards first, then evaluate the risk of injury from each hazard. Do not assume the risk is low until you evaluate the hazard. It is dangerous to overlook hazards. Job sites are especially dangerous because they are always changing. Many people are working at different tasks. Job sites are frequently exposed to bad weather. A reasonable place to work on a bright, sunny day might be very hazardous in the rain. The risks in your work environment need to be evaluated all the time. Then, whatever hazards are present need to be controlled.

Control hazards

Once electrical hazards have been recognized and evaluated, they must be controlled. You control electrical hazards in two main ways:

1. create a safe work environment and
2. use safe work practices.

One way to implement this safety model is to conduct a job hazard analysis (JHA). This involves development of a chart:

1. Column 1, breaking down the job into its separate task or steps;
2. Column 2, evaluating the hazard(s) of each task, and
3. Column 3, developing a control for each hazard. See the example below.

JHA: Changing a Wall Ground Fault Circuit Interrupter (GFCI)

Task analysis	Hazard analysis	Hazard abatement
Removing the cover	Electric shock from exposed live wires	De-energize by opening circuit breaker or removing fuse
Removing old GFCI	Possible other live wires in opening	Test wires with appropriate voltmeter to ensure all wires are de-energized
Installing new GFCI	Possible connecting wires incorrectly	Check wiring diagrams to ensure proper connections
Replace cover and re-energize	Possible defective GFCI	Test GFCI

Controlling electrical hazards (as well as other hazards) reduces the risk of injury or death.

OSHA regulations, the NEC, and the National Electrical Safety Code (NESC) provide a wide range of safety information.

Use the safety model to recognize, evaluate, and control workplace hazards like those in this photo.

Although these sources may be difficult to read and understand at first, with practice they can become very useful tools to help you recognize unsafe conditions and practices. Knowledge of OSHA standards is an important part of training for electrical apprentices. See the Appendix for a list of relevant standards.

Case Study

A maintenance man rode 12 feet above the floor on a motorized lift to work on a 227-volt light fixture. He did not turn off the power supply to the lights. He removed the line fuse from the black wire, which he thought was the “hot” wire. But, because of a mistake in installation, it turned out the white wire was the “hot” wire and not the black one. The black wire was neutral. He began to strip the white wire using a wire stripper in his right hand. Electricity passed from the “hot” white wire to the stripper, into his hand and through his body, and then to the ground through his left index finger. A co-worker heard a noise and saw the victim lying

face-up on the lift. She immediately summoned another worker, who lowered the platform. CPR was performed, but the maintenance man could not be saved. He was pronounced dead at the scene.

You can prevent injuries and deaths by remembering the following points:

- If you work on an electrical circuit, test to make sure the circuit is de-energized. (shut-off)
- Never attempt to handle any wires or conductors until you are absolutely positive their electrical supply has been shut off.
- Be sure to lock out and tag out circuits so they cannot be re-energized.
- Always assume a conductor is dangerous.

Module 4 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. Which of the following is not one of the steps in the Electrical Safety Model?

a. recognize hazards
b. organize risk
c. evaluate risk
d. control hazards

2. The first step of the Electrical Safety Model is ________ around you.

a. recognizing the hazards
b. evaluating the risk
c. correcting the hazards
d. identifying the risk

3. When evaluating hazards it is best to _________.

a. identify existing hazards
b. correct unique hazards first
c. report all common hazards
d. identify all possible hazards first

4. After identifying all possible hazards, the next step in the safety model is to ___________.

a. assess the probability of an accident
b. evaluate the risk of injury
c. analyze the severity of injury
d. correct the existing hazards

5. Once electrical hazards are recognized and evaluated for risk, how are they controlled?

a. create a safe environment
b. conduct post-injury investigation
c. use safe work practices
d. a and c above

Module 5: Recognizing Hazards

How do your recognize hazards?

The first step toward protecting yourself is recognizing the many hazards you face on the job. To do this, you must know which situations can place you in danger. Knowing where to look helps you to recognize hazards.

- Inadequate wiring is dangerous
- Exposed electrical parts are dangerous.
- Overhead power lines are dangerous.
- Wires with bad insulation can shock you.
- Electrical systems and tools that are not grounded or double-insulated are dangerous.
- Overloaded circuits are dangerous.
- Damaged power tools and equipment are electrical hazards.
- Using the wrong PPE is dangerous.
- Using the wrong tool is dangerous.
- Some on-site chemicals are harmful.
- Defective ladders and scaffolding are dangerous
- Ladders that conduct electricity are dangerous.

Electrical hazards can be made worse if the worker, location, or equipment is wet.

Case Study

An electrician was removing a metal fish tape from a hole at the base of a metal light pole. (A fish tape is used to pull wire through a conduit run.) The fish tape became energized, electrocuting him. As a result of its inspection, OSHA issued a citation for three serious violations of the agency's construction standards.

If the following OSH requirements had been followed, this death could have been prevented.

- De-energize all circuits before beginning work.
- Always lock out and tag out de-energized equipment.

- Companies must train workers to recognize and avoid unsafe conditions associated with their work.

Inadequate wiring hazards

Some definitions:

- *Wire gauge:* wire size or diameter (technically, the cross-sectional area.)
- *Ampacity:* the maximum amount of current a wire can carry safely without overheating.

Heads up: Inadequate or improper electrical wiring was one of OSHA's top 10 most commonly cited violations during 2011!! An electrical wiring hazard exists when the wire is too small for the current it will carry or is not connected properly. Normally, the circuit breaker in a circuit is matched to the wire size. However, in older wiring, branch lines to permanent ceiling light fixtures could be wired with a smaller gauge than the supply cable. Let's say a light fixture is replaced with another device that uses more current. The current capacity (ampacity) of the branch wire could be exceeded. When a wire is too small for the current it is supposed to carry, the wire will heat up. The heated wire could cause a fire.

When you use an extension cord, the size of the wire you are placing into the circuit may be too small for the equipment. The circuit breaker could be the right size for the circuit but not right for the smaller-gauge extension cord. A tool plugged into the extension cord may use more current than the cord can handle without tripping the circuit breaker. The wire will overheat and could cause a fire.

The kind of metal used as a conductor can cause an electrical hazard. Special care needs to be taken with aluminum wire. Since it is more brittle than copper, aluminum wire can crack and break more easily. Connections with aluminum wire can become loose and oxidize if not made properly, creating heat or arcing.

You must recognize that inadequate wiring is a hazard.

Case Study

A worker was attempting to correct an electrical problem involving two non-operational lamps. He examined the circuit in the area where he thought the problem was located. He had not shut off the power at the circuit breaker panel and didn't test the wires to see if they were live.

He was electrocuted when he grabbed the two live wires with his left hand. He collapsed to the floor and was found dead.

- Employers should not allow work to be done on electrical circuits unless an effective lock-out/tag-out program is in place.
- No work should be done on energized electrical circuits. Circuits must be shut off, locked out, and tagged out. Even then, you must test the circuit before beginning work to confirm that it is de-energized. ("dead")

Exposed electrical parts hazards

This hand-held sander has exposed wires and should not be used.

Electrical hazards exist when wires or other electrical parts are exposed. Wires and parts can be exposed if a cover is removed from a wiring or breaker box.

The overhead wires coming into a home may be exposed. Electrical terminals in motors, appliances, and electronic equipment may be exposed.

Older equipment may have exposed electrical parts. If you contact exposed live electrical parts, you will be shocked.

You must recognize that an exposed electrical component is a hazard.

Case Study

Five workers were constructing a chain-link fence in front of a house, directly below a 7,200-volt energized power line. As they prepared to install 21- foot sections of metal top rail on the fence, one of the workers picked up a section of rail and held it up vertically. The rail contacted the 7,200-volt line, and the worker was electrocuted. Following inspection, OSHA determined the employee who was killed had never received any safety training from his employer and no specific instruction on how to avoid the hazards associated with overhead power lines.

In this case, the company failed to obey these regulations:

- Employers must train their workers to recognize and avoid unsafe conditions on the job.
- Employers must not allow their workers to work near any part of an electrical circuit

unless the circuit is de-energized (shut-off) and grounded, or guarded in such a way it cannot be contacted.

- Ground-fault protection must be provided at construction sites to guard against electrical shock.

Approach boundaries

The risk from exposed live parts depends on your distance from the parts. Three “boundaries” are key to protecting yourself from electric shock and one to protect you from arc flashes or blasts. These boundaries are set by the National Fire Protection Association (NFPA 70E).

1. The limited approach boundary is the closest an unqualified person can approach, unless a qualified person accompanies you. A qualified person is someone who has received mandated training on the hazards and on the construction and operation of equipment involved in a task.
2. The restricted approach boundary is the closest to exposed live parts that a qualified person can go without proper PPE (such as, flame-resistant clothing) and insulated tools. When you're this close, if you move the wrong way, you or your tools could touch live parts. Same for the next boundary:
3. The prohibited approach boundary—the most serious—is the distance you must stay from exposed live parts to prevent flashover or arcing in air. Get any closer and it's like direct contact with a live part.

Electric Shock I Circuit Parts fo
Restricted Approa Boundary
1 ft.
Power source →

Electric Shock Boundaries to Live Circuit Parts for 100 V - 1 kV D-C	
Restricted Approach Boundary	Limited Approach Boundary
1 ft.	3 ft. 6 in.
Power source →	

To protect against burns, there's one more boundary: The flash protection boundary is where you need PPE to prevent incurable burns, if there's an arc flash.

Overhead powerline hazards

Electrical line workers need special training and equipment to work safely.

Most people do not realize that overhead powerlines are usually not insulated. More than half of all electrocutions are caused by direct worker contact with energized powerlines. Powerline workers must be especially aware of the dangers of overhead lines. In the past, 80% of all lineman deaths were caused by contacting a live wire with a bare hand. Due to such incidents, all linemen now wear special rubber gloves that protect them up to 34,500 volts. Today, most electrocutions involving overhead powerlines are caused by failure to maintain proper work distances.

Shocks and electrocutions occur where physical barriers are not in place to prevent contact with the wires. When dump trucks, cranes, work platforms, or other conductive materials (such as pipes and ladders) contact overhead wires, the equipment operator or other workers can be killed. If you do not maintain required clearance distances from powerlines, you can be shocked and killed. (The minimum distance for voltages up to 50kV is 10 feet. For voltages over 50kV, the minimum distance is 10 feet plus 4 inches for every 10 kV over 50kV.) Never store materials and equipment under or near over-head powerlines.


Operating a crane near overhead wires is very hazardous.

You need to recognize that overhead powerlines are a hazard.

Watch out for exposed electrical wires around electronic equipment.

Defective Insulation Hazards

This extension cord is damaged and should not be used.

Insulation that is defective or inadequate is an electrical hazard. Usually, a plastic or rubber covering insulates wires. Insulation prevents conductors from coming in contact with each other. Insulation also prevents conductors from coming in contact with people.

Extension cords may have damaged insulation. Sometimes the insulation inside an electrical tool or appliance is damaged. When insulation is damaged, exposed metal parts may become energized if a live wire inside touches them. Electric hand tools that are old, damaged, or misused may have damaged insulation inside. If you touch damaged power tools or other equipment, you will receive a shock. You are more likely to receive a shock if the tool is not grounded or double-insulated. (Double-insulated tools have two insulation barriers and no exposed metal parts.)

You must recognize that defective insulation is a hazard.

Improper Grounding Hazards

When an electrical system is not grounded properly, a hazard exists. The most common OSHA electrical violation is improper grounding of equipment and circuitry. The metal parts of an electrical wiring system that we touch (switch plates, ceiling light fixtures, conduit, etc.) should be grounded and at 0 volts. If the system is not grounded properly, these parts may become energized. Metal parts of motors, appliances, or electronics that are plugged into improperly grounded circuits may be energized. When a circuit is not grounded properly, a hazard exists because unwanted voltage cannot be safely eliminated. If there is no safe path to ground for fault currents, exposed metal parts in damaged appliances can become energized.

Extension cords may not provide a continuous path to ground because of a broken ground wire or plug. If you contact a defective electrical device that is not grounded, (or grounded improperly) you will be shocked.

You must recognize that an improperly grounded electrical system is a hazard.

Ground Fault Circuit Interrupters (GFCI)

A ground fault circuit interrupter, or GFCI, is an inexpensive life-saver. GFCI's detect any difference in current between the two circuit wires (the black wires and white wires). This difference in current could happen when electrical equipment is not working correctly, causing leakage current. If leakage current (a ground fault) is detected in a GFCI-protected circuit, the GFCI switches off the current in the circuit, protecting you from a dangerous shock. GFCI's are set at about 5 mA and are designed to protect workers from electrocution. GFCI's are able to detect the loss of current resulting from leakage through a person who is beginning to be shocked. If this situation occurs, the GFCI switches off the current in the circuit. GFCI's are different from circuit breakers because they detect leakage currents rather than overloads.

Circuits with missing, damaged, or improperly wired GFCI's may allow you to be shocked.

You must recognize that a circuit improperly protected by a GFCI is a hazard.

Overload hazards


Overloading leads to overheating of circut components (including wires) and may cause a fire

Overloads in an electrical system are hazardous because they can produce heat or arcing. Wires and other components in an electrical system or circuit have a maximum amount of current they can carry safely. If too many devices are plugged into a circuit, the electrical current will heat the wires to a very high temperature. If anyone tool uses too much current, the wires will heat up.

The temperature of the wires can be high enough to cause a fire. If their insulation melts, arcing may occur. Arcing can cause a fire in the area where the overload exists, even inside a wall.

In order to prevent too much current in a circuit, a circuit breaker or fuse is placed in the circuit. If there is too much current in the circuit, the breaker "trips" and opens like a switch. If an overloaded circuit is equipped with a fuse, an internal part of the fuse melts, opening the circuit. Both breakers and fuses do the same thing: open the circuit to shut off the electrical current.

If the breakers or fuses are too big for the wires they are supposed to protect, an overload in the circuit will not be detected and the current will not be shut off. Overloading leads to overheating of circuit components (including wires) and may cause a fire.

You must recognize that a circuit with improper overcurrent protection devices-or one with no overcurrent protection devices at all-is a hazard.

Overcurrent protection devices are built into the wiring of some electric motors, tools, and electronic devices. For example, if a tool draws too much current or if it overheats, the current will be shut off from within the device itself. Damaged tools can overheat and cause a fire.

You must recognize that a damaged tool is a hazard.

Wet conditions hazards

If you touch a live electrical component with an uninsulated hand tool you are more likely to receive a shock when standing in water.

Working in wet conditions is hazardous because you may become an easy path for electrical current. For instance, if you touch a live wire while standing in even a puddle of water, you will probably receive a shock.

Damaged insulation, equipment, or tools can expose you to live electrical parts. A damaged tool may not be grounded properly, so the housing of the tool may be energized, causing you to receive a shock. Improperly grounded metal switch plates and ceiling lights are especially hazardous in wet conditions. If you touch a live electrical component with an un-insulated hand tool, you are more likely to receive a shock when standing in water.

Remember: you don't have to be standing in water to be electrocuted. Wet clothing, high humidity, and perspiration also increase your chances of being electrocuted.

You need to recognize that all wet conditions are hazards.

Additional hazards

In addition to electrical hazards, other types of hazards are present at job sites. Remember that all of these hazards can be controlled.

- There may be chemical hazards. Solvents and other substances may be poisonous or cause disease.
- Frequent overhead work can cause tendinitis (inflammation) in your shoulders.

Intensive use of hand tools that involve force or twisting can cause tendinitis of the hands, wrists, or elbows. Use of hand tools can also cause carpal tunnel syndrome, which results when nerves in the wrist are damaged by swelling tendons or contracting muscles.

Module 5 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. Which of the following hazards is due to exposed electrical parts?

a. covers removed from breaker box
b. exposed electrical terminals on motors
c. overhead powerlines entering the building
d. all of the above are examples

2. Which of the following is not one of the three approach boundaries established by the National Fire Protection Agency (NFPA)?

a. limited approach boundary
b. restricted approach boundary
c. designated approach boundary
d. prohibited approach boundary

3. What is the cause of more than half of all electrocutions?

a. contact with energized powerlines
b. improper wiring
c. defective power tools
d. improperly grounded equipment

4. Which of the following is the most common OSHA electrical violation?

a. contact with energized powerlines
b. improper grounding
c. defective power tools
d. improperly insulated wires

5. If the breakers or fuses are too small for the wires they are supposed to protect, an overload in the circuit will not be detected and the current will not be shut off.

a. True
b. False

Module 6: Evaluating Risk

How Do You Evaluate Your Risk?

After you recognize a hazard, your next step is to evaluate your risk from the hazard. The closer you work to the "danger zone," the more likely you'll be exposed to the electrical hazard. For instance, exposed wires should be recognized as a hazard. If the exposed wires are 15 feet off the ground, you are not close to the danger zone so the risk is low. However, if you are going to be working on a roof near those same wires, your risk is high. The risk of shock is greater if you will be carrying metal conduit that could touch the exposed wires. It's important that as you work throughout the day, you must constantly evaluate your risk.


Combinations of hazards increase risks.

Another factor increasing your risk of injury is working around combinations of hazards. Improper grounding and a damaged tool greatly increase your risk. Wet conditions combined with other hazards also increase your risk. You will need to make decisions about the nature of hazards in order to evaluate your risk and do the right thing to remain safe.

There may be important clues that electrical hazards exist. For example, if a GFCI keeps tripping while you are using a power tool, that's a clue that there is a problem. Don't keep resetting the GFCI and continue to work. You must evaluate the "clue" and decide what action should be taken to control the hazard.

Any of these conditions, or "clues," tells you something important: there is a risk of fire and electrical shock. The equipment or tools involved must be avoided. You will frequently be caught in situations where you need to decide if these clues are present. A maintenance electrician, supervisor, or instructor needs to be called if there are signs of overload and you are not sure of the degree of risk. Ask for help whenever you are not sure what to do. By asking for help, you will protect yourself and others.

Case Study

An 18-year-old male worker, with 15 months of experience at a fast food restaurant, was plugging a toaster into a floor outlet when he received a shock. Since the restaurant was closed for the night, the floor had been mopped about 10 minutes before the incident. The restaurant manager and another employee heard the victim scream and investigated. The victim was found with one hand on the plug and the other hand grasping the metal receptacle box. His face was pressed against the top of the outlet. An employee tried to take the victim's pulse, but was shocked. The manager could not locate the correct breaker for the circuit. He then called the emergency squad, returned to the breaker box and found the correct breaker. By the time the circuit was opened, (turned off) the victim had been exposed to the current for 3 to 8 minutes. The employee checked the victim's pulse again and found it was very rapid.

The manager and the employee left the victim to unlock the front door and place another call for help. Another employee arrived at the restaurant and found the victim no longer had a pulse. The employee started CPR, which was continued by the rescue squad for nearly 90 minutes. The victim was dead on arrival at a local hospital.

Later, two electricians evaluated the circuit and found no serious problems. An investigation showed the victim's hand slipped forward when he was plugging in the toaster. His index finger made contact with an energized prong in the plug. His other hand was on the metal receptacle box, which was grounded. Current entered his body through his index finger, flowed across his chest, and exited through the other hand, which was in contact with the grounded receptacle.

To prevent death or injury, you must recognize hazards and take the right action.

- If the circuit had been equipped with a GFCI, the current would have been shut off before injury occurred.
- The recent mopping increased the risk of electrocution. Never work in wet or damp areas.
- Know the location of circuit breakers for your work area.

Conditions that point to electrical hazards

There are a number of other conditions that indicate an electrical hazard.

- Tripped circuit breakers and blown fuses show that too much current is flowing in a circuit. This condition could be due to several factors, such as malfunctioning equipment or a short between conductors. You need to determine the cause in order to control the hazard.
- An electrical tool, appliance, wire, or connection that feels warm may indicate too much current in the circuit or equipment. You need to evaluate the situation and determine your risk.
- An extension cord that feels warm may indicate too much current for the wire size of the cord. You must decide when action needs to be taken.
- A cable, fuse box, or junction box that feels warm may indicate too much current in the circuits.
- A burning odor may indicate overheated insulation.
- Worn, frayed, or damaged insulation around any wire or other conductor is an electrical hazard because the conductors could be exposed. Contact with an exposed wire could cause a shock. Damaged insulation could cause a short, leading to arcing or a fire. Inspect all insulation for scrapes and breaks. You need to evaluate the seriousness of any damage you find and decide how to deal with the hazard.
- A GFCI that trips indicates there is current leakage from the circuit. First, you must decide the probable cause of the leakage by recognizing any contributing hazards. Then, you must decide what action needs to be taken.

Case Study

A 20-year-old male laborer was carrying a 20-foot piece of iron from a welding shop to an outside storage rack. As he was turning a corner near a bank of electrical transformers, the top end of the piece of iron struck an uninsulated supply wire at the top of a transformer. Although the transformers were surrounded by a 6-foot fence, they were about 3 feet taller than the fence enclosure. Each transformer carried 4,160 volts.

When the iron hit the supply wire, the laborer was electrocuted. A forklift operator heard the iron drop to the ground at about 8:46 am and found the victim five minutes later. He was pronounced dead on arrival at a local hospital.

- According to OSHA, the enclosure around the transformers was too low. The fence should have been at least 8 feet tall.

- The company in this case didn't offer any formal safety training to its workers. All employers should develop safety and health training programs so their employees know how to recognize and avoid life-threatening hazards.

Module 6 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. Working with a defective electrical tool on wet ground would be an example of increased risk due to ______?

a. work on a construction site
b. location to the hazard
c. a combination of hazards
d. a single hazard type

2. A GFCI that keeps tripping is _____________.

a. an indication it is defective
b. expected and can be ignored
c. a normal indication
d. a clue that a hazard exists

3. Tripped circuit breakers and blown fuses show that _________.

a. the voltage is high
b. too little resistance
c. too much current is flowing
d. the AC frequency is too high

4. A ___________________ may indicate overheated insulation.

a. burning odor
b. buzzing sound
c. crack or split
d. broken wire

5. What does it mean when a GFCI trips?

a. a wire has been cut
b. current leakage from the circuit
c. the voltage has spiked
d. the circuit is closed

Module 7: Safe Work Environments

How Do You Control Hazards?

In order to control hazards, you must first create a safe work environment, then work in a safe manner. Generally, it is best to remove the hazards altogether and create an environment that is truly safe. When OSHA regulations and the NEC are followed, safe work environments are created.

But, you never know when materials or equipment might fail. Prepare yourself for the unexpected by using safe work practices. Use as many safeguards as possible. If one fails, another may protect you from injury or death.

How Do You Create a Safe Work Environment?

A safe work environment is created by controlling contact with electrical voltages and the currents they can cause. Electrical currents need to be controlled so they do not pass through the body. In addition to preventing shocks, a safe work environment reduces the chance of fires, burns, and falls.

You need to guard against contact with electrical voltages and control electrical currents in order to create a safe work environment. Make your environment safer by doing the following:

- Treat all conductors-even "de-energized" ones-as if they are energized until they are locked out and tagged.
- Lock out and tag out circuits and machines.
- Prevent overloaded wiring by using the right size and type of wire.
- Prevent exposure to live electrical parts by isolating them.
- Prevent exposure to live wires and parts by using insulation.
- Prevent shocking currents from electrical systems and tools by grounding them.
- Prevent shocking currents by using GFCI's.
- Prevent too much current in circuits by using overcurrent protection devices.

Case Study

At about 1:45 a.m., two journeyman electricians began replacing bulbs and making repairs on light fixtures in a spray paint booth at an automobile assembly plant. The job required the two electricians to climb on top of the booth and work from above. The top of the booth was filled

with pipes and ducts that restricted visibility and movement. Flashlights were required.

The electricians started at opposite ends of the booth. One electrician saw a flash of light, but continued to work for about 5 minutes, the climbed down for some wire. While cutting the wire, he smelled a burning odor and called to the other electrician. When no one answered, he climbed back on top of the booth. He found his co-worker in contact with a single-strand wire from one of the lights. Needle-nose wire strippers were stuck in the left side of the victim's chest. Apparently, he had been stripping insulation from an improperly grounded 530-volt, single-strand wire when he contacted it with the stripper. In this case, the electricians knew they were working on energized circuits. The breakers in both the booth's control panel were not labeled and the lock used for lock-out/tag-out was broken. The surviving electrician stated that locating the means to de-energize a circuit often takes more time than the actual job.

The electrician would be alive to if the following rules had been observed:

- Always shut off circuits-then test to confirm they are de-energized- before starting a job.
- Switchgear that shuts of a circuit must be clearly labeled and easy to access.
- Lock-out/tag-out materials must always be provided, and lock-out/tag-out procedures must always be followed.
- Always label circuit breakers.

Lock Out and Tag Out Circuits and Equipment

Lockout/tagout is an essential safety procedure that protects workers from injury while working on or near electrical circuits and equipment. Lock-out involves applying a physical lock to the power source(s) of circuits and equipment after they have been shut off and de-energized. The source is then tagged out with an easy-to-read tag that alerts other workers in the area that a lock has been applied.

In addition to protecting workers from electrical hazards, lock-out/tag-out prevents contact with operating equipment parts: blades, gears, shafts, presses, etc. Read more about Lockout/Tagout by taking OSHAcademy Course 710.

Always test a circuit to make sure it is de-energized before working on it.

Lock-out tag-out saves lives.

Scenario #1

An employee was cutting a metal pipe using a blowtorch. Diesel fuel was mistakenly discharged into the line and was ignited by his torch. The worker burned to death at the scene.

Remember: All valves along the line should have been locked out, blanked out, and tagged out to prevent the release of fuel. Blanking is the process of inserting a metal disk into the space between two pipe pipe flangers. The disk, or blank, is then bolted in place to prevent passage of liquids or gases through the pipe.

Scenario #2

A worker was replacing a V-belt on a dust collector. Before beginning work, he shut down the unit at the local switch. However, an operator in the control room restarted the unit using a remote switch. The worker's hand was caught between the pulley and belts of the blower, resulting in cuts and a fractured finger.

Remember: When performing lock-out/tag-out on machinery, you must always lock out and tag out ALL energy sources to the machinery.

Also, lock-out/tag-out prevents the unexpected release of hazardous gasses, fluids, or solid matter in areas where workers are present.

**OSHA defines a "qualified person" as someone who has received mandated training on the hazards and on the construction and operation of equipment involved in a task.*

Control Inadequate Wiring Hazards

Electrical hazards result from using the wrong size or type of wire. You must control such hazards to create a safe work environment. You must choose the right size wire for the amount of current expected in a circuit. The wire must be able to handle the current safely. The wire's insulation must be appropriate for the voltage and tough enough for the environment. Connections need to be reliable and protected.

Wires come in different sizes. The maximum current each size can conduct safely is shown.

Control Hazards of Fixed Wiring

The wiring methods and size of conductors used in a system depend on several factors:

- Intended use of the circuit system
- Building materials
- Size and distribution of electrical load
- Location of equipment (such as underground burial)
- Environmental conditions (such as dampness)
- Presence of corrosives
- Temperature extremes

Fixed, permanent wiring is better than extension cords, which can be misused and damaged more easily. NEC requirements for fixed wiring should always be followed. A variety of materials can be used in wiring applications, including nonmetallic sheathed cable (Romex®), armored cable, and metal and plastic conduit. The choice of wiring material depends on the wiring environment and the need to support and protect wires.

Aluminum wire and connections should be handled with special care. Connections made with aluminum wire can loosen due to heat expansion and oxidize if they are not made properly. Loose or oxidized connections can create heat or arcing. Special clamps and terminals are necessary to make proper connections using aluminum wire. Antioxidant paste can be applied to connections to prevent oxidation.

Control Hazards of Flexible Wiring


Nonmetallic sheathing helps protect wires from damage.

Electrical cords supplement fixed wiring by providing the flexibility required for maintenance, portability, isolation from vibration, and emergency and temporary power needs.

Flexible wiring can be used for extension cords or power supply cords. Power supply cords can be removable or permanently attached to the appliance.

DO NOT use flexible wiring in situations where frequent inspection would be difficult, where damage would be likely, or where long-

term electrical supply is needed. Flexible cords cannot be used as a substitute for the fixed wiring of a structure. Flexible cords must not be:

- Run through holes in walls, ceilings, or floors;
- Run through doorways, windows, or similar openings (unless physically protected);
- Attached to building surfaces (except with a tension take-up device within 6 feet of the supply end);
- Hidden in walls, ceilings, or floors; or
- Hidden in conduit or other raceways.

Use the Right Extension Cord

The size of wire in an extension cord must be compatible with the amount of current the cord will be expected to carry. The amount of current depends on the equipment plugged into the extension cord. Current ratings (how much current a device needs to operate) are often printed on the nameplate. If a power rating is given, it is necessary to divide the power rating in watts by the voltage to find the current rating. For example, a 1,000-watt heater plugged into a 120-volt circuit will need almost 10 amps of current. Let's look at another example: A 1-horsepower electric motor uses electrical energy at the rate of almost 750 watts, so it will need a minimum of about 7 amps of current on a 120-volt circuit. But, electric motors need additional current as they startup or if they stall, requiring up to 200% of the nameplate current rating. Therefore, the motor would need 14 amps.

Add to find the total current needed to operate all the appliances supplied by the cord. Choose a wire size that can handle the total current.

American Wire Gauge (AWG)	
Wire size	Handles up to
#10 AWG #12 AWG #14 AWG #16 AWG	30 amps 25 amps 18 amps 13 amps
Remember: The larger the gauge number, the smaller the wire!	

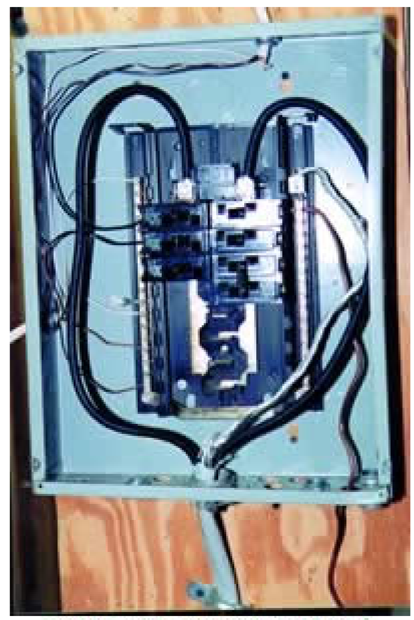
The length of the extension cord also needs to be considered when selecting the wire size. Voltage drops over the length of a cord. If a cord is too long, the voltage drop can be enough to damage

equipment. Many electric motors only operate safely in a narrow range of voltages and will not work properly at voltages different than the voltage listed on the nameplate. Even though light bulbs operate (somewhat dimmer) at lowered voltages, do not assume electric motors will work correctly at less-than-required voltages. Also, when electric motors start or operate under load, they require more current. The larger the size of the wire, the longer a cord can be without causing a voltage drop that could damage tools and equipment.

The grounding path for extension cords must be kept intact to keep you safe. A typical extension cord grounding system has four components:

- a third wire in the cord, called a ground wire;
- a three-prong plug with a grounding prong on one end of the cord;
- a three-wire, grounding-type receptacle at the other end of the cord; and
- a properly grounded outlet.

Control Hazards of Exposed Live Electrical Parts: Isolate Energized Components


Use covers to prevent accidental contact with electrical circuits.

Electrical hazards exist when wires or other electrical parts are exposed. These hazards need to be controlled to create a safe work environment. Isolation of energized electrical parts makes them inaccessible unless tools and special effort are used. Isolation can be accomplished by placing the energized parts at least 8 feet high and out of reach, or by guarding. Guarding is a type of isolation that uses various structures-like cabinets, boxes, screens, barriers, covers, and partitions-to close-off live electrical parts.

Take the following precautions to prevent injuries from contact with live parts:

- Immediately report exposed live parts to a supervisor or teacher. As a student, you should never attempt to correct the condition yourself without supervision.
- Use covers, screens, or partitions for guarding that require tools to remove them.
- Replace covers that have been removed from panels, motors, or fuse boxes.

- Even when live parts are elevated to the required height (8 feet), care should be taken when using objects (like metal rods or pipes) that can contact these parts.
- Close unused conduit openings in boxes so that foreign objects (pencils, metal chips, conductive debris, etc.) cannot get inside and damage the circuit.

Control Hazards of Exposure to Live Electrical Wires: Use Proper Insulation

Insulation is made of material that does not conduct electricity (usually plastic, rubber, or fiber). Insulation covers wires and prevents conductors from coming in contact with each other or any other conductor. If conductors are allowed to make contact, a short circuit is created. In a short circuit, current passes through the shorting material without passing through a load in the circuit, and the wire becomes overheated.

This cover cannot be removed without special tools.

Insulation keeps wires and other conductors from touching, which prevents electrical short circuits. Insulation prevents live wires from touching people and animals, thus protecting them from electrical shock.

Insulation helps protect wires from physical damage and conditions in the environment. Insulation is used on almost all wires, except some ground wires and some high-voltage transmission lines. Insulation is used internally in tools, switches, plugs, and other electrical and electronic devices.

Special insulation is used on wires and cables that are used in harsh environments. Wires and cables that are buried in soil must have an outer covering of insulation that is flame-retardant and resistant to moisture, fungus, and corrosion.

In all situations, you must be careful not to damage insulation while installing it. Do not allow staples or other supports to damage the insulation. Bends in a cable must have an inside radius of at least 5 times the diameter of the cable so that insulation at a bend is not damaged. Extension cords come with insulation in a variety of types and colors. The insulation of extension cords is especially important. Since extension cords often receive rough handling, the insulation can be damaged. Extension cords

might be used in wet places, so adequate insulation is necessary to prevent shocks. Because extension cords are often used near combustible materials (such as wood shavings and sawdust) a short in an extension cord could easily cause arcing and a fire.

Insulation on individual wires is often color-coded. In general, insulated wires used as equipment grounding conductors are either continuous green or green with yellow stripes. The grounded conductors that complete a circuit are generally covered with continuous white or gray insulation. The ungrounded conductors, or "hot" wires, may be any color other than green, white, or gray. They are usually black or red.

Conductors and cables must be marked by the manufacturer to show the following:

- Maximum voltage capacity,
- AWG size,
- Insulation-type letter, and
- The manufacturer's name or trademark.

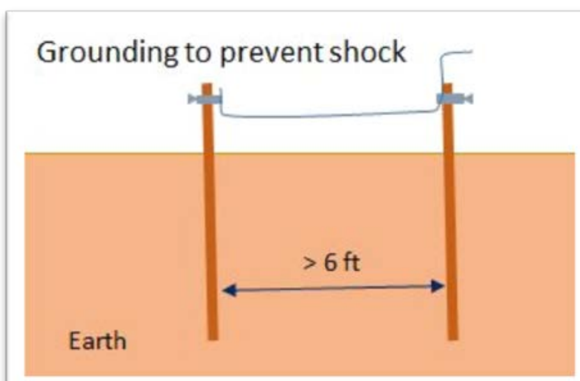
Ground Electrical Devices.

Ground circuits and equipment

When an electrical system is not grounded properly, a hazard exists. This is because the parts of an electrical wiring system that a person normally touches may be energized, or live, relative to ground. Parts like switch plates, wiring boxes, conduit, cabinets, and lights need to be at 0 volts relative to ground. If the system is grounded improperly, these parts may be energized. The metal housings of equipment plugged into an outlet need to be grounded through the plug.

Grounding is connecting an electrical system to the earth with a wire. Excess or stray current travels through this wire to grounding rods buried in the earth. Rods used for grounding should be:

- made of 5/8th inch copper or steel
- at least 2 feet from a foundation wall
- located at least 6 feet apart
- driven into the ground to an 8 foot depth



Sometimes an electrical system will receive a higher voltage than it is designed to handle. These high voltages may come from a lightning strike, line surge, or contact with a higher-voltage line. Sometimes a defect occurs in a device that allows exposed metal parts to become energized. Grounding will help protect the person working on a system, the system itself, and others using tools or operating equipment connected to the system. The extra current produced by the excess voltage travels relatively safely to the earth.

Grounding is connecting an electrical system to the earth with a wire. Excess or stray current travels through this wire to a grounding device (commonly called a "ground") deep in the earth. Grounding prevents unwanted voltage on electrical components. Metal plumbing is often used as a ground. When plumbing is used as a grounding conductor, it must also be connected to a grounding device such as a conductive rod. (Rods used for grounding must be driven at least 8 feet into the earth.) Sometimes an electrical system will receive a higher voltage than it is designed to handle. These high voltages may come from a lightning strike, line surge, or contact with a higher-voltage line. Sometimes a defect occurs in a device that allows exposed metal parts to become energized. Grounding will help protect the person working on a system, the system itself, and others using tools or operating equipment connected to the system. The extra current produced by the excess voltage travels relatively safely to the earth.

Grounding creates a path for currents produced by unintended voltages on exposed parts. These currents follow the grounding path, rather than passing through the body of someone who touches the energized equipment. However, if a grounding rod takes a direct hit from a lightning strike and is buried in sandy soil, the rod should be examined to make sure it will still function properly. The heat from a lightning strike can cause the sand to turn into glass, which is an insulator. A grounding rod must be in contact with damp soil to be effective.

Leakage current occurs when an electrical current escapes from its intended path. Leakages are sometimes low-current faults that can occur in all electrical equipment because of dirt, wear, damage, or moisture. A good grounding system should be able to carry off this leakage current. A ground fault occurs when current passes through the housing of an electrical device to ground. Proper grounding protects against ground faults. Ground faults are usually caused by misuse of a tool or damage to its insulation. This damage allows a bare conductor to touch metal parts or the tool housing.

When you ground a tool or electrical system, you create a low-resistance path to the earth (known as a ground connection). When done properly, this path has sufficient current-carrying capacity to eliminate voltages that may cause a dangerous shock.

Grounding does not guarantee that you will not be shocked, injured, or killed from defective equipment. However, it greatly reduces the possibility.

Equipment needs to be grounded under any of these circumstances:

- The equipment is within 8 feet vertically and 5 feet horizontally of the floor or walking surface.
- The equipment is within 8 feet vertically and 5 feet horizontally of grounded metal objects you could touch.
- The equipment is located in a wet or damp area and is not isolated.

The equipment is connected to a power supply by cord and plug and is not double-insulated.

Use Ground Fault Circuit Interrupters (GFCI's)

The use of GFCI's has lowered the number of electrocutions dramatically. A GFCI is a fast-acting switch that detects any difference in current between two circuit conductors. If either conductor comes in contact-either directly or through part of your body-with a ground (a situation known as a ground fault), the GFCI opens the circuit in a fraction of a second. If a current as small as 4 to 6 mA does not pass through both wires properly, but instead leaks to the ground, the GFCI is tripped. The current is shut off.


Portable GFCI

There is a more sensitive kind of GFCI called an isolation GFCI. If a circuit has an isolation GFCI, the ground fault current passes through an electronic sensing circuit in the GFCI. The electronic sensing circuit has enough resistance to limit current to as little as 2 mA, which is too low to cause a dangerous shock.

GFCI's are usually in the form of a duplex receptacle. They are also available in portable and plug-in designs and as circuit breakers that protect an entire branch circuit. GFCI's can operate on both two- and three-wire ground systems. For a GFCI to work properly, the neutral conductor (white wire) must (1) be continuous, (2) have low resistance, and (3) have sufficient current-carrying capacity.

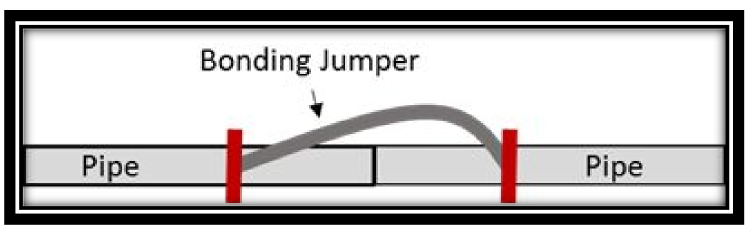
GFCI's help protect you from electrical shock by continuously monitoring the circuit. However, a GFCI does not protect a person from line-to-line hazards such as touching two "hot" wires (240 volts) at the same time or touching a "hot" and neutral wire at the same time. Also be aware that instantaneous currents can be high when a GFCI is tripped. A shock may still be felt. Your reaction to the shock could cause injury, perhaps from falling.

Test GFCI's regularly by pressing the "test" button. If the circuit does not turn off, the GFCI is faulty and must be replaced.

The NEC requires that GFCI's be used in these high-risk situations:

- Electricity is used near water.
- The user of electrical equipment is grounded (by touching grounded material).
- Circuits are providing power to portable tools or outdoor receptacles.
- Temporary wiring or extension cords are used.
- Specifically, GFCI's must be installed in bathrooms, garages, out-door areas, crawl spaces, unfinished basements, kitchens, and near wet bars.

Bond Components to Assure Grounding Path



In order to assure a continuous, reliable electrical path to ground, a bonding jumper wire is used to make sure electrical parts are connected. Some physical connections, like metal conduit coming into a box, might not make a good electrical connection because of paint or possible corrosion. To make a good electrical connection, a bonding jumper needs to be installed.

A bonding jumper is a conductor used to connect parts to be bonded. Bonding assures electrical continuity between electrical components. Any fault current will be conducted along the bonded metal to ground.

Additionally, interior metal plumbing must be bonded to the ground for electrical service equipment in order to keep all grounds at the same potential (0 volts). Even metal air ducts should be bonded to electrical service equipment.

Control Overload Current Hazards

When a current exceeds the current rating of equipment or wiring, a hazard exists. The wiring in the circuit, equipment, or tool cannot handle the current without heating up or even melting. Not only will the wiring or tool be damaged, but the high temperature of the conductor can also cause a fire. To prevent this from happening, an overcurrent protection device (circuit breaker or fuse) is used in a circuit. These devices open a circuit automatically if they detect current in excess of the current rating of equipment or wiring. This excess current can be caused by an overload, short circuit, or high-level ground fault.

Overcurrent protection devices are designed to protect equipment and structures from fire. They do not protect you from electrical shock! Overcurrent protection devices stop the flow of current in a circuit when the amperage is too high for the circuit. A circuit breaker or fuse will not stop the relatively small amount of current that can cause injury or death. Death can result from 20 mA (.020 amps) through the chest. A typical residential circuit breaker or fuse will not shut off the circuit until a current of more than 20 amps is reached!

But overcurrent protection devices are not allowed in areas where they could be exposed to physical damage or in hazardous environments. Overcurrent protection devices can heat up and occasionally arc or spark, which could cause a fire or an explosion in certain areas. Hazardous environments are places that contain flammable or explosive materials such as flammable gasses or vapors (Class I Hazardous Environments), finely pulverized flammable dusts (Class II Hazardous Environments), or fibers or metal filings that can catch fire easily (Class III Hazardous Environments). Hazardous environments may be found in aircraft hangars, gas stations, storage plants for flammable liquids, grain silos, and mills where cotton fibers may be suspended in the air. Special electrical systems are required in hazardous environments.


Only circuit breakers marked "SWD" should be used as switches.

If an overcurrent protection device opens a circuit, there may be a problem along the circuit. (In the case of circuit breakers, frequent tripping may also indicate that the breaker is defective.) When a circuit breaker trips or a fuse blows, the cause must be found.

A circuit breaker is one kind of overcurrent protection device. It is a type of automatic switch located in a circuit. A circuit breaker trips when too much current passes through it. A circuit breaker should not be used regularly to turn power on or off in a circuit, unless the breaker is designed for this purpose and marked "SWD" (stands for "switching device").

A fuse is another type of overcurrent protection device. A fuse contains a metal conductor that has a relatively low melting point. When too much current passes through the metal in the fuse, it heats up within a fraction of a second and melts, opening the circuit. After an overload is found and corrected, a blown fuse must be replaced with a new one of appropriate amperage.

Module 7 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. In order to control hazards, you must first work in a safe manner and then create a safe work environment.

a. true
b. false

2. Which of the following is an essential safety procedure that protects workers from injury while working on or near electrical circuits and equipment?

a. Fire prevention
b. Hazard communication
c. Lockout/Tagout
d. Confined space entry

3. In which of the following situations is it safe to use flexible wiring?

a. damage is likely
b. long-term electrical supply is needed
c. inspection is difficult
d. none of the above

4. To be properly isolated, energized electrical parts must be inaccessible unless ____________.

a. tools and special efforts are used
b. a guard is placed to keep people away
c. the parts are six feet above ground
d. proper PPE is used

5. A ______________________ is a fast-acting switch that detects any difference in current between two circuit conductors.

a. double-blind actuator
b. ground fault circuit interrupter
c. current limiting switch
d. series circuit diode

Module 8: Working on Live Circuits

When You Must Work on or Near Live Circuits

Working on live circuits means actually touching energized parts. Working near live circuits means working close enough to energized parts to put you at risk even though you may be working on de-energized parts.

Common tasks where you need to work on or near live circuits include:

- taking voltage and current measurements,
- opening and closing disconnects and circuit breakers,
- racking circuit breakers on and off the bus,
- removing panels and dead fronts, and
- opening electric equipment doors for inspection.

There should be standard written procedures and training for these common tasks. For instance, when opening and closing disconnects, use the left-hand rule when possible (stand to the right side of equipment with a disconnect on the right, and operate the disconnect with your left hand). For other situations where you might need to work on or near live circuits, your employer should institute a written live-work permit system, which must be authorized by a qualified supervisor.

Case Study

A 40-year-old male meter technician had just completed a 7-week basic lineman training course. He worked as a meter technician during normal working hours and as a lineman during unplanned outages. One evening, he was called to repair a residential power outage. By the time he arrived at the site of the outage, he had already worked 2 hours of overtime and worked 14 straight hours the day before. At the site, a tree limb had fallen across an overhead powerline. The neutral wire in the line was severed, and the two energized 120-volt wires were disconnected. The worker removed the tree limb and climbed up a power pole to reconnect the three wires. He was wearing insulated gloves, a hard hat, and some safety goggles.

He prepared the wires to be connected. While handling the wires, one of the energized wires caught the cuff of his left glove and pulled the cuff down. The conductor contacted the victim's forearm near the wrist. He was electrocuted and fell backwards. He was wearing a climbing belt, which left him hanging upside down from the pole. Paramedics arrived 5 minutes after

the contact. The power company lowered his dead body 30 minutes later.

Several factors may have contributed to this incident. Below are some ways to eliminate these risk factors:

- Ask for assistance when you are assigned tasks that cannot be safely completed alone. The task assigned to the victim could not have been done safety by only one person.
- Do not work overtime performing hazardous tasks that are not part of your normal assignments.
- Employees should only be given tasks they are qualified to perform. All employees below the journeyman level should be supervised.

Live-work permit system

A live-work permit should, at least, contain this information:

- a description of the circuit and equipment to be worked on and the location,
- explanation why the work must be done "live"
- date and time covered by the permit
- a description of the safe work practices to be used
- results of shock hazard analysis and determination of shock protection boundaries
- results of flash hazard analysis and determination of the flash protection boundary
- PPE needed to safely perform the job
- who will do the work and how unqualified persons will be kept away
- evidence of completion of job briefing, including discussion of job-specific hazards
- energized-work approval signatures (authorizing or approving management, safety officer, owner, etc.)

Case Study

A company was contracted to install wiring and fixtures in a new office complex. The third floor was being prepared in a hurry for a new tenant, and daily changes to the electrical system blueprints were arriving by fax. The light fixtures in the office were mounted in a metal grid that was fastened to the ceiling and properly grounded.

A 23-year-old man apprentice electrician was working on a light fixture when he contacted an energized conductor. He came down from the fiberglass ladder and collapsed. Apparently, he had contacted the “hot” conductor while also in contact with the metal grid. Current passed through his body and into the grounded grid. Current always takes a path to the ground. In this case, the worker was part of that path.

He was dead on arrival at a nearby hospital. Later, an investigation showed the victim had cross-wired the conductors in the fixture by mistake. This incorrect wiring allowed electricity to flow from the live circuit on the completed section of the building to the circuit on which the victim was working.

Below are some safety procedures that should have been followed in this case. Because they were ignored, the job ended in death.

- Before work beings, all circuits in the immediate work area must be shut off, locked out, and tagged out- then tested to confirm they are de-energized.
- Wiring done by apprentice electricians should be checked by a journeyman.
- Supervisors should always review changes to an original blueprint in order to identify any new hazards the changes might create.

Safe Work Practices

To work on or near live parts, you must do the following:

- Have a written live-work permit for the work to be done.
- Wear the right PPE to protect against electric shock and arc flash. Never wear clothing made from synthetic materials, such as acetate, nylon, polyester, polypropylene, or rayon - alone or combined with cotton. Such clothing is dangerous because it can burn and melt into your skin.

The PPE that is needed depends on the type of electric work being done. The minimum PPE required while working on line circuits would be an untreated natural fiber long-sleeve shirt and long pants plus safety glasses with side shields. Depending on the voltage and the electric task to be done, different types of PPE are required. Fire-resistant protective clothing can include multi-layer flash suit jacket and pants, wraparound face shield, double-layer switching hood, voltage-rated gloves with leather protectors, electrically rated hard hats, and so forth. [(See Table 130.7(C)(15)(A)(b) Arc-Flash Hazard PPE Categories for A/C systems, Table 130.7(C)(15)(B) Arc-Flash Hazard PPE Categories for D/C Systems, and Table 130.7(C)(16) Personal Protective Equipment (PPE)) NFPA 70E, 2015 Edition]

- Use the proper type of protective equipment, such as insulated tools and/or handling equipment that is rated for the voltage. These can include insulated fuse or fuse holding equipment, nonconductive ropes and handlines, fiberglass-reinforced plastic rods, nonconductive portable ladders (such as, fiberglass), protective shields, rubber insulating equipment, voltage-rated plastic guards, and so forth.

Case Study

A lineman (the victim) was killed after contacting a 17,400-volt charge switch. The victim was part of a three-man crew replacing cables under a switch cabinet. At the time of the accident, the crew was feeding a new cable under the concrete foundation pad below the cabinet. As one worker pushed the cable under the foundation, the victim looped the cable inside the foundation under the cabinet. The victim was using a hot stick to loop the cable but was not wearing his hard hat when his head came either in close proximity to or contacted the charged switch. Crewmembers saw a flash and came around the switch cabinet to where the victim was located. He was found slumped partially in the cabinet. A crewmember used a hot stick to move the victim away from the cabinet and then began CPR. Emergency medical services transported the victim to a nearby hospital where he was declared dead from injuries associated with high-voltage electrocution.

Based on the findings in the investigation, to prevent similar incidents, employers should:

- Ensure workers use personal protective equipment and enforce its use.
- Ensure workers are capable of recognizing and avoiding hazardous situations.
- Emphasize de-energizing, isolating, or cover energized work areas whenever personnel need to work within high voltage danger zones.

Module 8 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. Working on live circuits means working close enough to energized parts to put you at risk.

a. true
b. false

2. When using the "left-hand rule," the worker will stand _____________ the disconnect.

a. the left side of
b. the right side of
c. to either side of
d. to the front of

3. Where you might need to work on or near live circuits, your employer should institute a written ________ system, which must be authorized by a qualified supervisor.

a. live-work permit
b. hot-work permit
c. tagout permit
d. confined space entry permit

4. A live-work permit does not contain this information:

a. date and time covered by the permit
b. PPE needed to safely perform the job
c. oxygen level within the work space
d. energized-work approval signatures

5. According to the text, the _________ PPE required while working on live circuits would be an untreated natural fiber long-sleeve shirt and long pants plus safety glasses with side shields.

a. minimum
b. maximum
c. typical
d. standard

Module 9: Safe Work Practices

How Do You Work Safely?

A safe work environment is not enough to control all electrical hazards. You must also work safely. Safe work practices help you control your risk of injury or death from workplace hazards. If you are working on electrical circuits or with electrical tools and equipment, you need to use safe work practices.

Before you begin a task, ask yourself:

- What could go wrong?
- Do I have the knowledge, tools, and experience to do this work safely?

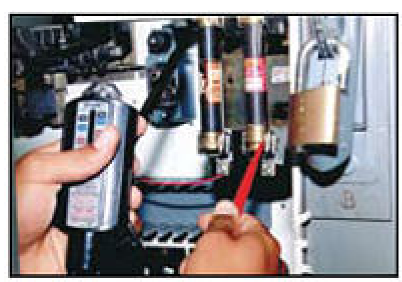
All workers should be very familiar with the safety procedures for their jobs. You must know how to use specific controls that help keep you safe. You must also use good judgment and common sense.

Control electrical hazards through safe work practices.

- Plan your work and plan for safety.
- Avoid wet working conditions and other dangers.
- Avoid overhead powerlines.
- Use proper wiring and connectors.
- Use and maintain tools properly.
- Wear correct PPE.

Plan Your Work and Plan for Safety

Take time to plan your work, by yourself and with others. Safety planning is an important part of any task. It takes effort to recognize, evaluate, and control hazards. If you are thinking about your work tasks or about what others think of you, it is hard to take the time to plan for safety. But, YOU MUST PLAN.



Test circuits to make sure they are de-energized.

Planning with others is especially helpful. It allows you to coordinate your work and take advantage of what others know about identifying and controlling hazards. The following is a list of some things to think about as you plan.

This worker is applying a group lock-out device. The equipment cannot be re-started until all workers remove their locks.

- Work with a buddy-Do not work alone. Both of you should be trained in CPR. Both of you must know what to do in an emergency.
- Know how to shut off and de-energize circuits-You must find where circuit breakers, fuses, and switches are located. Then, the circuits that you will be working on (even low-voltage circuits) MUST BE TURNED OFF! Test the circuits before beginning work to make sure they are completely de-energized.
- Plan to lock out and tag out circuits and equipment - Make certain all energy sources are locked out and tagged out before performing any work on an electrical circuit or electrical device. Working on energized ("hot") circuits is one of the most dangerous things any worker could do. If someone turns on a circuit without warning, you can be shocked, burned, or electrocuted. The unexpected starting of electrical equipment can cause severe injury or death.

Before ANY work is done on a circuit, shut off the circuit, lock out and tag out the circuit at the distribution panel, then test the circuit to make sure it is de-energized.

Before ANY equipment inspections or repairs-even on so-called low-voltage circuits-the current must be turned off at the switch box, and the switch must be padlocked in the OFF position. At the same time, the equipment must be securely tagged to warn everyone that work is being performed. Again, test circuits and equipment to ensure they are de-energized.

No two locks should be alike. Each key should fit only one lock, and only one key should be issued to each worker. If more than one worker is working on a circuit or repairing a piece of equipment, each worker should lock out the switch with his or her own lock and never permit anyone else to remove it. At all times, you must be certain that you are not exposing other workers to danger. Workers who perform lock-out/tag-out must be trained and authorized to repair and maintain electrical equipment. A locked-out switch or feeder panel prevents others from turning on a circuit. The tag informs other workers of your action.

- Remove jewelry and metal objects - Remove jewelry and other metal objects or apparel from your body before beginning work. These things can cause burns if worn near high currents and can get caught as you work.
- Plan to avoid falls - Injuries can result from falling off scaffolding or ladders. Other workers may also be injured from equipment and debris falling from scaffolding and ladders.

- DO not do any tasks that you are not trained to do or that you do not feel comfortable doing!

Case Study

A crew of 7 workers was painting a 33-foot sign at a shopping mall. The crew used tubular welded frame scaffolding that was 31 feet tall and made up of several tiers. The sign was partially painted when the crew was instructed to move the scaffolding so the concrete could be poured for an access road. The crew moved the scaffolding 30 fee without disassembling it. An overhead powerline was located about 10 feet away from the scaffolding. After the concrete was hardened, the workers lifted the scaffolding to move it back to the sign. The top tier came loose, fell, and contacted the powerline. All seven workers were knocked away from the scaffolding. Two died; five were hospitalized.

You must take certain precautions when working with scaffolding.

- Scaffolding should not be moved until all potential safety hazards are identified and controlled. In this case, the scaffolding should have taken apart before it was moved.
- Locking pins must be used to secure tiers to one another.
- Always make sure you have enough time to complete your assignment safely. If you are rushed, you may be more likely to take deadly shortcuts. (such as failing to dismantle scaffolding before moving it)
- Employers must have a written safety program that includes safe work procedures and hazard recognition.

Avoid Overhead Powerlines

Be very careful not to contact overhead powerlines or other exposed wires. More than half of all electrocutions are caused by contact with overhead lines. When working in an elevated position near overhead lines, avoid locations where you (and any conductive object you hold) could contact an unguarded or un-insulated line. You should be at least 10 feet (3.05 meters) away from high-voltage transmission lines.

Vehicle operators should also pay attention to overhead wiring. Dump trucks, front-end loaders, and cranes can lift and make contact with overhead lines. If you contact equipment that is touching live wires, you will be shocked and may be killed. If you are in the vehicle, stay inside. Always be aware of what is going on around you.

Case Study

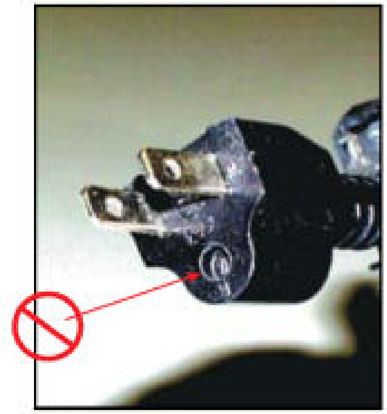
A worker from an electrical service company was changing bulbs in pole-mounted light fixtures in a shopping center parking lot. The procedure for installing the bulbs was as follows: The worker would park the truck near the first light pole. The truck was equipped with a roof-mounted ladder. The worker would extend the ladder high enough to change the bulb, and then drive to the next pole without lowering the ladder.

After the worker replaced the first bulb, he got back in the truck and drove toward the next light pole. As the truck moved along, a steel cable attached to the top of the ladder contacted an overhead powerline. The worker realized something was wrong, stopped the truck and stepped onto the pavement while still holding onto the door of the truck. By doing this, he completed the path to ground for the current in the truck. Because the ladder was still in contact with the powerline, the entire truck was now energized. He was engulfed in flames as the truck caught fire. Fire, police, and paramedic units arrived within five minutes. Utility workers arrived in about 10 minutes and de-energized the powerline. The victim burned to death at the scene.

Below are some ways to prevent contact with overhead powerlines:

- A safe distance must be maintained between ladders (and other equipment) and overhead powerlines. OSHA requires a clearance of at least 10 feet be maintained between aerial ladders and overhead powerlines of up to 50,000 volts.
- Moving a truck with the ladder is a dangerous practice. One way to control this hazard is to install an engine lock that prevents a truck's engine from starting unless the ladder is fully retracted.
- If there are overhead powerlines in the immediate area, lighting systems that can be serviced from ground level are recommended for safety.
- If the worker had been trained properly, he may have known to stay inside the truck.
- Job hazard analysis should always be performed to identify and control hazards. In this case, a survey would have identified the powerlines as a possible hazard, and appropriate hazard control measure (such as lowering the ladder between installations) could have been taken.

Use Proper Wiring and Connectors



Never use a three-prong grounding plug with the ground prong broken off.

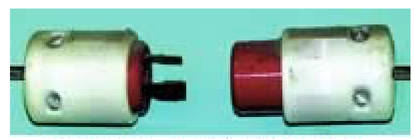
- Avoid overloads - Do not overload circuits.
- Test GFCI's - Test GFCI's monthly using the "test" button.
- Check switches and insulation - Tools and other equipment must operate properly. Make
  sure that switches and insulating parts are in good condition.
- Use three-prong plugs - Never use a three-prong grounding plug with the third prong broken-off. When using tools that require a third-wire ground, use only three-wire extension cords with three-prong grounding plugs and three-hole electrical out-lets. Never remove the grounding prong from a plug! You could be shocked or expose someone else to a hazard. If you see a cord without a grounding prong in the plug, remove the cord from service immediately.

Portable GFCI.

- Use extension cords properly - If an extension cord must be used, choose one with sufficient ampacity for the tool being used. An undersized cord can overheat and cause a drop in voltage and tool power. Check the tool manufacturer's recommendations for the required wire gauge and cord length. Make sure the insulation is intact. To reduce the risk of damage to a cord's insulation, use cords with insulation marked "S" (hard service) rather than cords marked "SJ" (junior hard service). Make sure the grounding prong is intact. In damp locations, make sure wires and connectors are waterproof and approved for such locations. Do not create a tripping hazard.
- Check power cords and extensions - Electrical cords should be inspected regularly using the following procedure:
    1. Remove the cord from the electrical power source before inspecting.
    2. Make sure the grounding prong is present in the plug.
    3. Make sure the plug and receptacle are not damaged.
    4. Wipe the cord clean with a diluted detergent and examine for cuts, breaks, abrasions, and defects in the insulation.

5. Coil or hang the cord for storage. Do not use any other methods. Coiling or hanging is the best way to avoid tight kinks, cuts, and scrapes that can damage insulation or conductors.

- You should also test electrical cords regularly for ground continuity using a continuity tester as follows:
    1. Connect one lead of the tester to the ground prong at one end of the cord.
    2. Connect the second lead to the ground wire hole at the other end of the cord.
    3. If the tester lights up or beeps (depending on design), the cord's ground wire is okay. If not, the cord is damaged and should not be used.
- Do not pull on cords - Always disconnect a cord by the plug.
- Use correct connectors - Use electrical plugs and receptacles that are right for your current and voltage needs. Connectors are designed for specific currents and voltages so that only matching plugs and receptacles will fit together. This safeguard prevents a piece of equipment, a cord, and a power source with different voltage and current requirements from being plugged together. Standard configurations for plugs and receptacles have been established by the National Electric Manufacturers Association (NEMA).



Locking-type attachment plug.

Use and Maintain Tools Properly

Hand and power tools are a common part of our everyday lives and are present in nearly every industry. These tools help us to easily perform tasks that otherwise would be difficult or impossible. However, these simple tools can be hazardous and have the potential for causing severe injuries when used or maintained improperly. Special attention toward hand and power tool safety is necessary in order to reduce or eliminate these hazards.

This cord has been spliced using a wire nut. Spliced cords are very dangerous!

Your tools are at the heart of your craft. Tools help you do your job with a high degree of quality. Tools can do something else, too. They can cause injury or even death! You must use the right tools for the job. Proper maintenance of tools and other equipment is very important. Inadequate maintenance can cause equipment to

deteriorate, creating dangerous conditions. You must take care of your tools so they can help you and not hurt you.

- Inspect tools before using them - Check for cracked casings, dents, missing or broken parts, and contamination (oil, moisture, dirt, corrosion). Damaged tools must be removed from service and properly tagged. These tools should not be used until they are repaired and tested.
- Use the right tool correctly - Use tools correctly and for their intended purposes. Follow the safety instructions and operating procedures recommended by the manufacturer. When working on a circuit, use approved tools with insulated handles.

Note: DO NOT USE THESE TOOLS TO WORK ON ENERGIZED CIRCUITS. ALWAYS SHUT OFF AND DE-ENERGIZE CIRCUITS BEFORE BEGINNING WORK ON THEM.

Don't work on energized circuits like this one! Always follow correct lock-out/tag-out procedures.

- Protect your tools - Keep tools and cords away from heat, oil, and sharp objects. These hazards can damage insulation. If a tool or cord heats up, stop using it! Report the condition to a supervisor or instructor immediately. If equipment has been repaired, make sure that it has been tested and certified as safe before using it. Never carry a tool by the cord. Disconnect cords by pulling the plug-not the cord!
- Use double-insulated tools - Portable electrical tools are classified by the number of insulation barriers between the electrical conductors in the tool and the worker. The NEC permits the use of portable tools only if they have been approved by Underwriter's Laboratories (UL Listed). Equipment that has two insulation barriers and no exposed metal parts is called double-insulated. When used properly, double-insulated tools provide reliable shock protection without the need for a third ground wire. Power tools with metal housings or only one layer of effective insulation must have a third ground wire and three-prong plug.
- Use multiple safe practices - Remember: A circuit may not be wired correctly. Wires may contact other "hot" circuits. Someone else may do something to place you in danger. Take all possible precautions.

Case Study

An employee was climbing a metal ladder to hand an electrical drill to the journeyman installer on a scaffold about 5 feet above him. When the victim reached the third rung of the ladder, he received an electrical shock that killed him. An investigation showed the grounding prong was missing from the extension cord attached to the drill. Also, the cord's green grounding wire was, at times, contacting the energized black wire. Because of this contact with the "hot" wire, the entire length of the grounding wire and the drill's frame became energized. The drill was not double-insulated.

To avoid deadly incidents like this one, take these precautions:

- Make certain that approved GFCI's or equipment grounding systems are used at construction sites.
- Use equipment that provides a permanent and continuous path to ground. Any fault current will be safely diverted along this path.
- Inspect electrical tools and equipment daily and remove damaged or defective equipment from use right away.

Wear Correct PPE

OSHA requires that you be provided with personal protective equipment. This equipment must meet OSHA requirements and be appropriate for the parts of the body that need protection and the work performed. There are many types of PPE: rubber gloves, insulating shoes and boots, face shields, safety glasses, hard hats, etc. Even if laws did not exist requiring the use of PPE, there would still be every reason to use this equipment. PPE helps keep you safe. It is the last line of defense between you and the hazard.

- Wear safety glasses - Wear safety glasses to avoid eye injury.
- Wear proper clothing - Wear clothing that is neither floppy nor too tight. Loose clothing will catch on corners and rough surfaces. Clothing that binds is uncomfortable and distracting.
- Contain and secure loose hair - Wear your hair in such a way that it does not interfere with your work or safety.

- Wear proper foot protection - Wear shoes or boots that have been approved for electrical work. (Tennis shoes will not protect you from electrical hazards.) If there are non-electrical hazards present (nails on the floor, heavy objects, etc.), use footwear that is approved to protect against these hazards as well.
- Wear a hard hat - Wear the proper class of hard hat to protect your head from bumps, falling objects and electrical hazards. Hard hats should be worn with the bill forward to protect you properly.
- Wear hearing protectors - Wear hearing protectors in noisy areas to prevent hearing loss.
- Follow directions - Follow the manufacturer's directions for cleaning and maintaining PPE.
- Make an effort - Search out and use any and all equipment that will protect you from shocks and other injuries.

Arcing electrical burns through the victim's shoe and around the rubber sole.

Module 9 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. This practice allows you to coordinate your work and take advantage of what others know about identifying and controlling hazards.

a. pre-plan your work
b. read the manual
c. plan with others
d. ask for help

2. The electrical circuits that you will be working on, even low-voltage circuits, must be turned off.

a. true
b. false

3. Which of the following should be done before beginning work on electrical circuits?

a. remove jewelry
b. re-energize the circuit
c. test circuit paths
d. replace guards

4. When performing work, you should be at least ______ away from high-voltage transmission lines.

a. 5 feet (1.5 meters)
b. 8 feet (2.4 meters)
c. 10 feet (3.05 meters)
d. 15 feet (4.6 meters)

5. Double-insulated equipment must meet which of the following two criteria?

a. two insulation barriers, no exposed parts
b. two safety switches, guarded parts
c. no insulation barriers, two exposed parts
d. no exposed parts or insulation barriers

Module 10: Electrical Protective Equipment

Care and Use of Electrical Protective Equipment

To prevent injury from exposure to electrical conductors, it's important that all electrical protective equipment be maintained in a safe, reliable condition. Electrical protective equipment includes the following:

- insulating blankets;
- covers;
- line hose;
- gloves; and
- sleeves made of rubber.

All electrical protective equipment made of rubber should meet the established safety standards and specifications discussed below.

Note: For more on this topic, see Course 715, Electrical Safety Basics.

Voltages

Maximum use voltages must conform to those listed in Table I-4.

Table I-4: Rubber Insulating Equipment Voltage Requirements

Class of Equipment (ac - rms)	Maximum Use Voltage[1]	Retest Voltage[2] (ac - rms)	Restest Voltage[2] (dc - avg)
0	1,000	5,000	20,000
1	7,500	10,000	40,000
2	17,000	20,000	50,000
3	26,500	30,000	60,000
4	36,000	40,000	70,000

Footnote(1) The maximum use voltage is the a-c voltage (rms) classification of the protective equipment that designates the maximum nominal design voltage of the energized system that may be safely worked. The nominal design voltage is equal to the phase-to-phase voltage on multiphase circuits. However, the phase-to-ground potential is

considered to be the nominal design voltage:

[1] if there is no multiphase exposure in a system area and if the voltage exposure is limited to the phase-to-ground potential; or

[2] if the electrical equipment and devices are insulated or isolated or both so that the multiphase exposure on a grounded wye circuit is removed.

Footnote (2) The proof-test voltage must be applied continuously for at least 1 minute, but no more than 3 minutes.

Inspecting Equipment

To make sure electrical protective equipment actually performs as designed, it must be inspected for damage before each day's use and immediately following any incident that can reasonably be suspected of having caused damage. Insulating gloves must be given an air test, along with the inspection.

Defects

Insulating equipment must not be used if any of the following defects are detected:

- a hole, tear, puncture, or cut;
- ozone cutting or ozone checking (the cutting action produced by ozone on rubber under mechanical stress into a series of interlacing cracks);
- an embedded foreign object;
- changes in the texture including, swelling, softening, hardening, or becoming sticky or inelastic; or
- any other defect that damages the insulating properties.

Insulating equipment found to have other defects that might affect its insulating properties must be removed from service and returned for testing. It must be cleaned as needed to remove foreign substances. It must be stored in such a location and in such a manner to protect it from:

- light;
- temperature extremes;
- excessive humidity;

- ozone; and
- other injurious substances and conditions.

Gloves

Protector gloves must be worn over insulating gloves. An exception is when using Class 0 gloves, under limited-use conditions, where small equipment and parts manipulation necessitate unusually high finger dexterity. But, it's important to note that extra care must be taken while visually examining the glove. Also, make sure to avoid handling sharp objects.

Any other class of glove may be used for similar work without protector gloves if the employer can demonstrate that the possibility of physical damage to the gloves is small and if the class of glove is one class higher than that required for the voltage involved. Insulating gloves that have been used without protector gloves may not be used at a higher voltage until they have been tested.

Testing

Electrical protective equipment must be subjected to periodic electrical tests. Test voltages and the maximum intervals between tests must be in accordance with Table I-4 and Table I-5.

Table I-5: Rubber Insulating Equipment Test Intervals

Type of Equipment	When to Test
Rubber insulating line hose	Upon indication that insulating value is suspect and after repair.
Rubber insulating covers	Upon indication that insulating value is suspect and after repair.
Rubber insulating blankets	Before first issue and every 12 months thereafter[1] upon indication that insulating value is suspect; and after repair.
Rubber insulating gloves	Before first issue and every 6 months thereafter[1] upon indication that insulating value is suspect; after repair; and after use without protectors.
Rubber insulating sleeves	Before first issue and every 12 months thereafter[1] upon indication that insulating value is suspect; and after repair.

Footnote (1) If the insulating equipment has been electrically tested but not issued for service, it may not be placed into service unless it has been electrically tested within the previous 12 months.

The test method used must reliably indicate whether the insulating equipment can withstand the voltages involved. Repaired insulating equipment must be retested before it may be used by employees.

Note: Standard electrical test methods considered as meeting this requirement are given in the national consensus standards of The American Society for Testing and Materials (ASTM).

If the insulating equipment fails to pass inspections or electrical tests it may not be used by employees. Below is a list of exceptions.

- Rubber insulating line hose may be used in shorter lengths with the defective portion cut off.
- Rubber insulating blankets may be repaired using a compatible patch that results in physical and electrical properties equal to those of the blanket.
- Rubber insulating blankets may be salvaged by severing the defective area from the undamaged portion of the blanket. The resulting undamaged area may not be smaller than 22 inches by 22 inches (560 mm by 560 mm) for Class 1, 2, 3, and 4 blankets.
- Rubber insulating gloves and sleeves with minor physical defects, such as small cuts, tears, or punctures, may be repaired by the application of a compatible patch. Also, rubber insulating gloves and sleeves with minor surface blemishes may be repaired with a compatible liquid compound. The patched area must have electrical and physical properties equal to those of the surrounding material. Repairs to gloves are permitted only in the area between the wrist and the reinforced edge of the opening.

Certification

The employer must certify that equipment has been tested in accordance with the requirements of the standard, and the certification must identify the equipment that passed the test and the date it was tested.

Marking equipment and entering the results of the tests and the testing dates onto logs are two acceptable ways to meet this requirement.

Module 10 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

1. According to Table I-4, below, the maximum use ac-rms voltage for class 1 rubber equipment is: ______.

a. 1,000
b. 7,500
c. 10,000
d. 40,000

Table I-4: Rubber Insulating Equipment Voltage Requirements

Class of Equipment (ac - rms)	Maximum Use Voltage[1]	Retest Voltage[2] (ac - rms)	Restest Voltage[2] (dc - avg)
0	1,000	5,000	20,000
1	7,500	10,000	40,000
2	17,000	20,000	50,000
3	26,500	30,000	60,000
4	36,000	40,000	70,000

2. To make sure electrical protective equipment actually performs as designed, it must be inspected for damage: ________.

a. at the end of each quarter
b. prior to the beginning of a work shift
c. monthly and following any incident causing damage
d. before each day's use and following any incident in which damage is suspected

3. According to the text, insulating equipment may still be used if you detect which of the following defects?

a. holes, tears, punctures or cuts
b. ozone cutting or checking
c. embedded foreign object
d. change in color

4. Which of the following is not a requirement if insulating equipment is found to have "other" defects that might affect insulating properties?

a. removal from service and tested
b. cleaned as needed
c. disposal
d. protection from injurious conditions

5. To certify electrical protective equipment has been tested, it is recommended that the employer: _______.

a. mark the equipment
b. record the results of the test
c. record the date of the test
d. all of the above

